# APPENDIX E

## SELECTED SITE SUMMARIES OF PREVIOUS PERMEABLE BARRIER APPLICATIONS FOR CHLORINATED SOLVENT PLUMES

**SITE 1: BELFAST, NORTHERN IRELAND, Electronics Manufacturing Facility**

SITE CHARACTERISTICS:
A plume with concentrations of TCE up to 390 mg/L is located in a comer of the site that is characterized by a thick deposit of till (up to 24 meters) underlain by Mercia Mudstones. The till has silt, sand, and gravel lenses that alIow contaminant to migrate some distance from source. Orientation of the more permeable horizons influence the migration pathways. Groundwater flow is towards the NE comer of the site.

BENCH-SCALE TESTS:

*Column test:* The columns were filled with 100% granular iron with a measured porosity value of 0.48. Tests were conducted at room temperature at two different flow velocities: 109 cm/d and 54 cm/d. Water collected from the site was used in the column experiments.

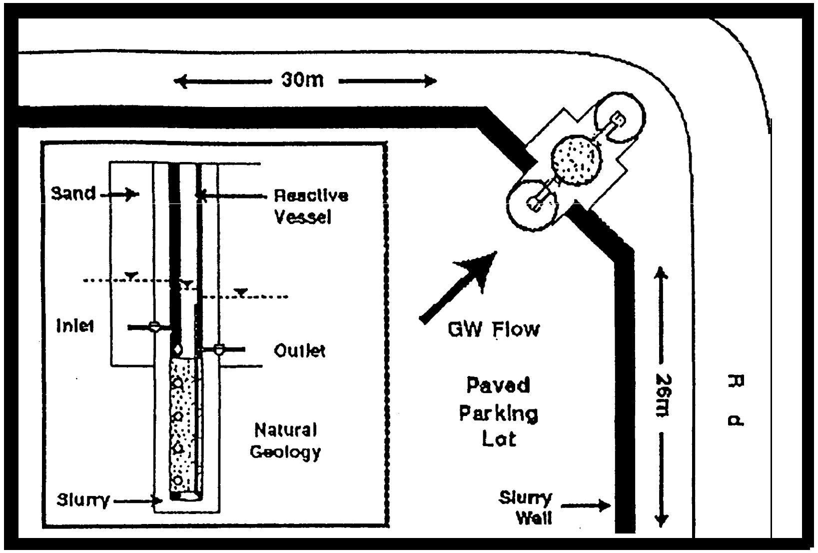
*Half-lives:* At flow velocities of 109cm/d and 54 cm/d, TCE had half-lives of 1.2 and 3.7 hours respectively, and *cis*-1,2-dichloroethene (cDCE) had half-lives of 12.5 and 23.9 hours respectively. Some VC (100-300 µg/L) was produced.

*lnorganic results:* Unlike most studies, pH did not increase, probably because of the high concentration of dissolved organics in the groundwater. There was a marked increase in iron in column effluent from the corrosion of iron metal by water. Production of chloride ions occurred.

*Implications for the field.* Precipitates could slow down degradation rates of VOC, although this has not occurred in other sites. Groundwater monitoring of the pilot-scale unit would be used to determine extent and location of precipitates. Water velocities combined with half-lives will determine the thickness of the gate.

FULL-SCALE FIELD TEST:
(Figure E-1)
*System:* Funnel and gate
*Funnel:* Bentonite cement slurry walls
*Gate:* Cylindrical reactive vessel filled with iron
*Design:* 80 to 100 ft of slurry walls on either side of in situ reactor
*Monitoring:* Monitoring points at various locations in cylinder
*Other:* Groundwater modeling (FLOWPATH) was used in aid of design

COST:
Installation costs: $350,000
iron media: $20,000



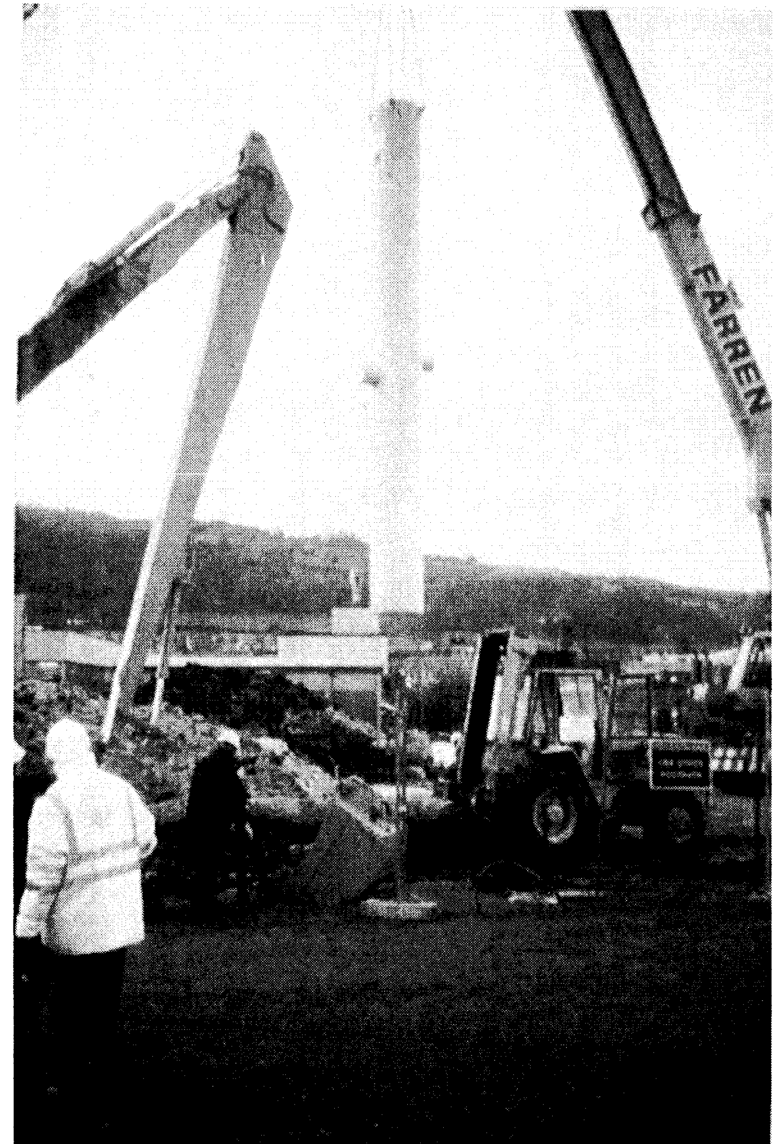




Figure E-l. Funnel-and-Gate System Installed at an Electronics Manufacturing Facility in Belfast, Northern Ireland. Above Schematic Shows Both the Plan View and the Sectional View of the Installation. At Right, the Reactive Vessel is Ready for Emplacement (ETI, 1997)

**SITE 2: KANSAS, DOE Kansas City Plant**

SITE CHARACTERISTICS:
An alluvial aquifer about 35 to 40 feet in thickness overlies shale and sandstone bedrock. A contaminant plume occurs in the basal alluvial sand and gravel zone at a depth of 30 feet. Water flows NE and discharges into the Blue River. An existing interceptor trench captures the plume, and an ultraviolet oxidation treatment system treats it. Maximum concentrations of cDCE, VC, and TCE are 1,500 μg/L, 90 μg/L, and 200 μg/L respectively.

BENCH-SCALE TESTS:

*Column tests:* Columns were filled with 100% reactive iron. Tests were conducted at room temperature at flow velocities of 1.9 ft/d and 6.0 ft/d. Groundwater collected from the site contained 200 μg/L TCE, 1,300 μg/L cDCE, and 90 μg/L VC. Groundwater also contained 225 mg/L Ca, and alkalinity ranged from 350 to 780 mg/L $HCO^{-3}$. The column was 100 cm in length, with an inner diameter of 2.54 cm. Samples were taken every 5 pore volumes until steady state was reached. Porosity losses due to inorganic precipitates from 2 to 15% per year have been predicted based on lab column results, although this is likely to be significantly less.

*Half-lives:* At flow velocities of 1.9 ft/d and 6.0 ft/d, the half-life of TCE was 1.0 hr and 0.6 hr respectively; cDCE was 3.5 and 3.5 hrs, and VC was 6.0 hours and NA.

*Inorganic results:* Ca, Mg, and alkalinity concentration dropped. Dissolved iron and pH increased. Carbonate mineral precipitation formed, as well as iron hydroxide precipitate (when pH was at or above 9).

*Implications for field:* Because influent was oversaturated with calcite prior to entering the column, precipitation might not occur to the same extent in situ, as oversaturation may be caused by dissolution of $C0_2$ during sampling.

PILOT-SCALE FIELD TEST:
1,000-foot funnel-and-gate system was installed at the property boundary in January of 1996. A high funnel-to-gate ratio (490-foot funnel on either side of 20-foot-long gate) could be constructed because of low groundwater velocity. The type of funnel was a soil-bentonite slurry wall. The gate was excavated in the center of the slurry wall after slurry was allowed to set (Figure E-2). The reactive zone is composed of 100% iron and separated by 2 feet of pea gravel. It was placed from 30 to 17 feet below ground surface (vertical thickness of 12 feet) and had a flowthrough thickness of about 3 feet. Excavated soil was placed from the top of the reactive zone to the ground surface. Residence time of water through the iron is 56.1 hours. The FLOWPATH groundwater flow model was used to study the effect of the funnel-and-gate on existing groundwater flow patterns.

COSTS:
Construction: $350,000.
Iron Media (~70 tons of granular iron): $50,000.
Total Cost: $400,000.
The cost of installing a full-scale multigate system at this site could range from 0.75M to 1.2M dollars.

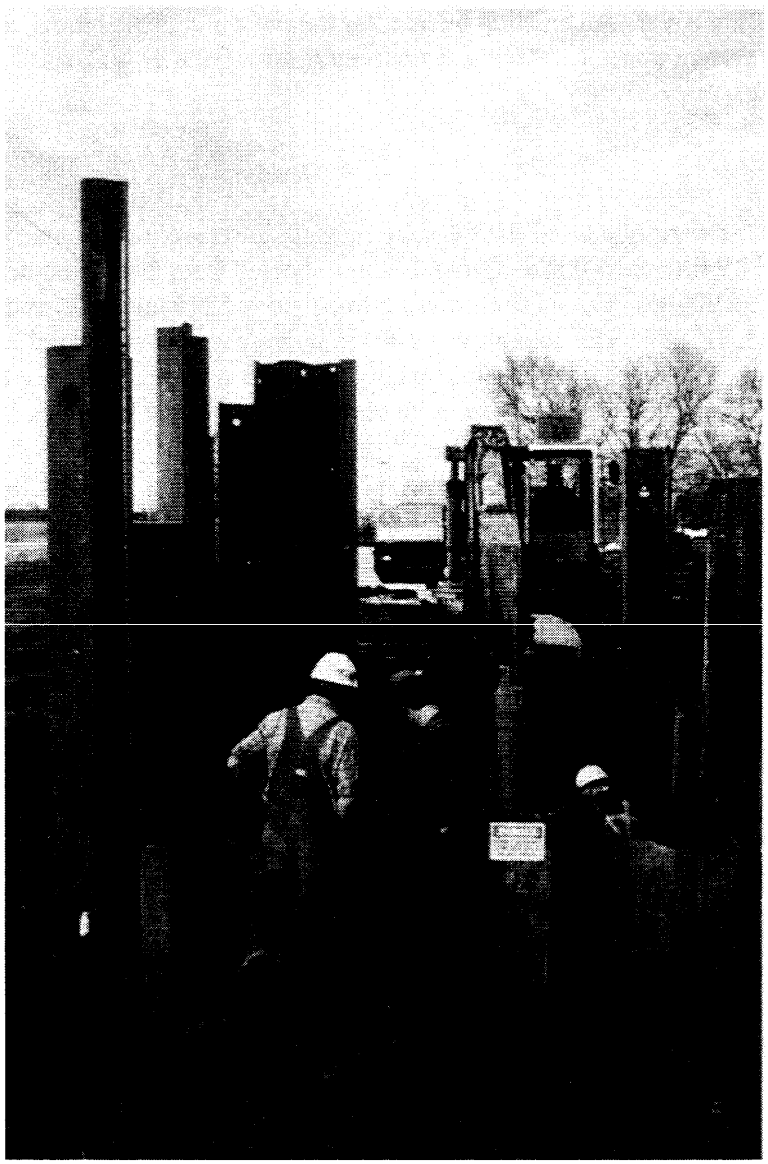


**Figure E-2. Initial Excavation of a Gate in the Center of the Slurry Funnel Wall, DOE Kansas City Plant (ETI, 1997)**

## SITE 3: NEW YORK, Industrial Facility

SITE CHARACTERISTICS:
The plume is located in a shallow aquifer and contains concentrations up to 300 ppb of TCE, up to 500 ppb of cDCE, and up to 80 ppb of VC.

BENCH-SCALE TESTS:
NA

PILOT-SCALE FIELD TEST:
In situ funnel-and-gate was installed in May 1995 (Figure E-3). A 12-foot-wide, 3.5-foot-thick central reactive section is flanked by 15 feet of sheet piling extending laterally on either side. The reactive section keyed into a clay layer located approximately 14 to 15 feet below the ground surface. Velocity though the zone is about 1 foot/day and a portion (about 24 feet wide) of the plume is being captured and treated.

*Monitoring:* Monitored through the EPA Superfund Innovative Technology Evaluation Program for six months, through the summer and fall of 1995. VOC concentrations have been reduced to MCLs within 1.5 feet of travel through the reactive media.

COSTS:
10 days to complete installation. Cost for installation was $250,000, which included $30,000 for approximately 45 tons of iron. Preliminary microbial analyses of groundwater samples indicated that the system operation should not be significantly inhibited by biofouling.

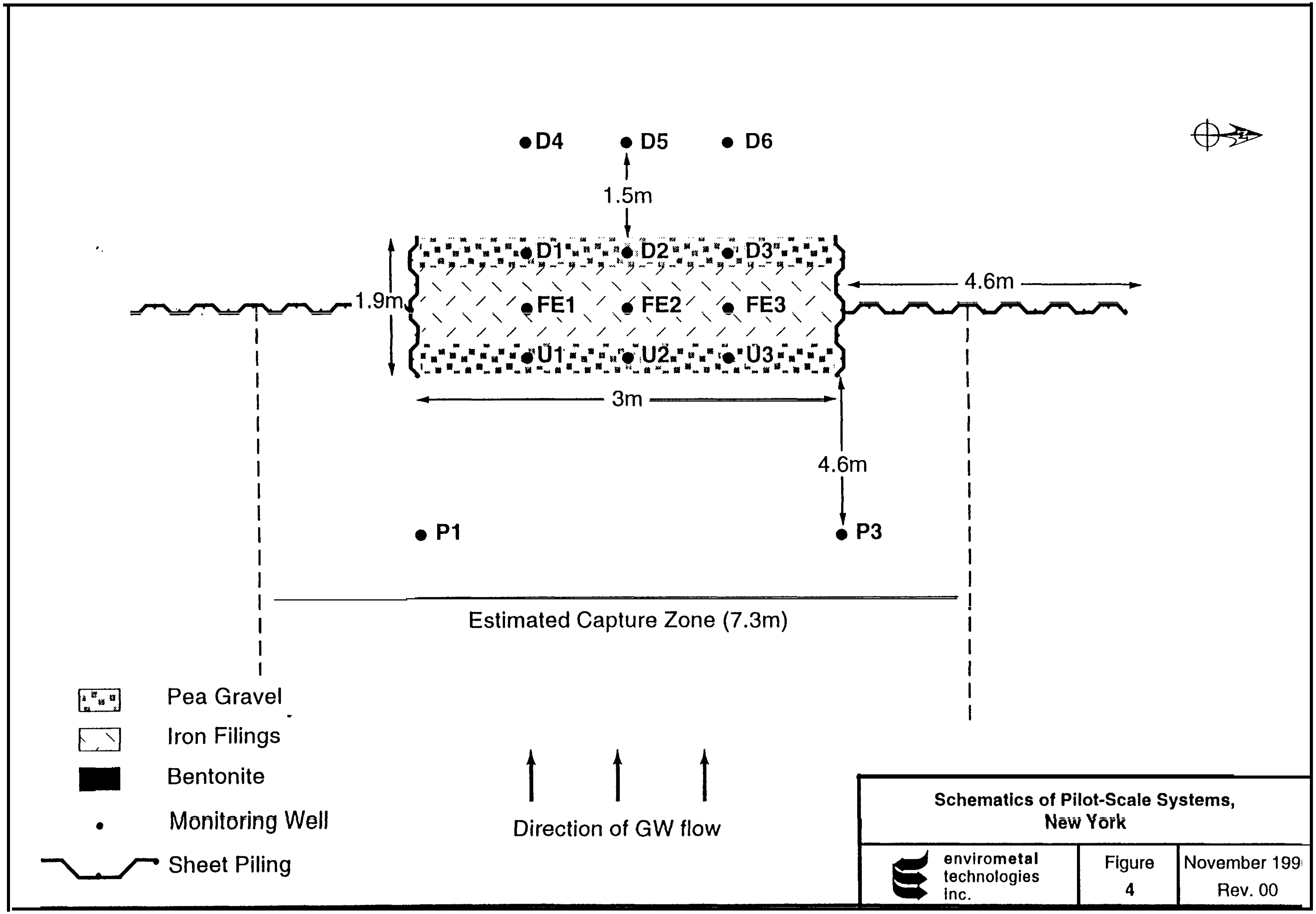



**Figure E-3. Design Plan for Permeable Barrier Installed at an Industrial Facility, New York (ETI, 1996)**

## SITE 4: INTERSIL, Semiconductor Manufacturing Facility, Sunnyvale, CA

SITE CHARACTERISTICS:
Shallow groundwater, located within an upper 10m of overburden containing interlayering sands and sandy silt, has a flowrate of one ft/d. A 65-foot-thick clay layer at greater depth acts as an aquitard. The plume contains TCE, cl ,2-DCE, VC, and Freon 113. Groundwater flow varies to the northwest and to the north-northeast.

BENCH-SCALE TESTS:

*Column tests:* Degradation rates were high in reactive media containing 15% iron.

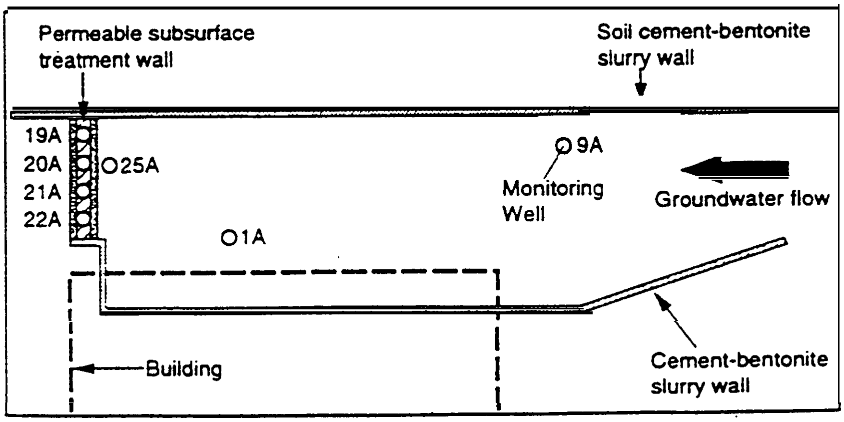
*Half-lives:* A field test reactor (a large fiberglass canister containing 50% iron and 50% sand by weight) used a flow velocity at 4 ft/d for 9 months. TCE had a half-life of 1.7 hours; cDCE, 1-4 hours; VC, 2-4 hours; Freon 113, less than 1.6 hours.

*Inorganic results:* Highly mineralized precipitate formation was evident at effluent end, but the rate of degradation remain relatively constant over 9 months. Since the system has been operating, no precipitates have been found. Other tests also indicated no need for hydrogen gas collection or microbe growth beyond background level.

FULL-SCALE FIELD TEST:
A funnel-and-gate system was installed in December 1994 (Figure E-4). The permeable barrier is located in the northeast corner of the site and extends about 40 feet along the property line. Installation proceeded by driving sheet piling to the appropriate depth and then excavating the sheet piling cell. The treatment wall is keyed into slurry walls (a 300-foot slurry wall on one side of containment area and a 235-foot on the other) on eastern and western ends. The reactive cell placed 20 feet below the surface is 40-foot-wide, has 4-foot flowthrough thickness, is made of 100% granular iron, and has a vertical thickness of 13 feet. Two feet of higher permeability pea gravel up- and downgradient of the barrier allows uniform flow of groundwater through the iron. Residence time of the groundwater in the reactive cell is approximately 4 days.

*Monitoring:* Four monitoring wells were installed within the last 4 inches of the subsurface treatment wall near its downgradient side to collect groundwater samples for performance monitoring.

COSTS:
Pump and treat system had O & M costs $300,000 per year, with a projected O & M cost of $8 million for a 30-year period. Capital cost of the permeable barrier was $720,000 ($170,000 for iron media) with a projected O & M cost of $2 million for monitoring and replacing every 10 years over the 30-year period.



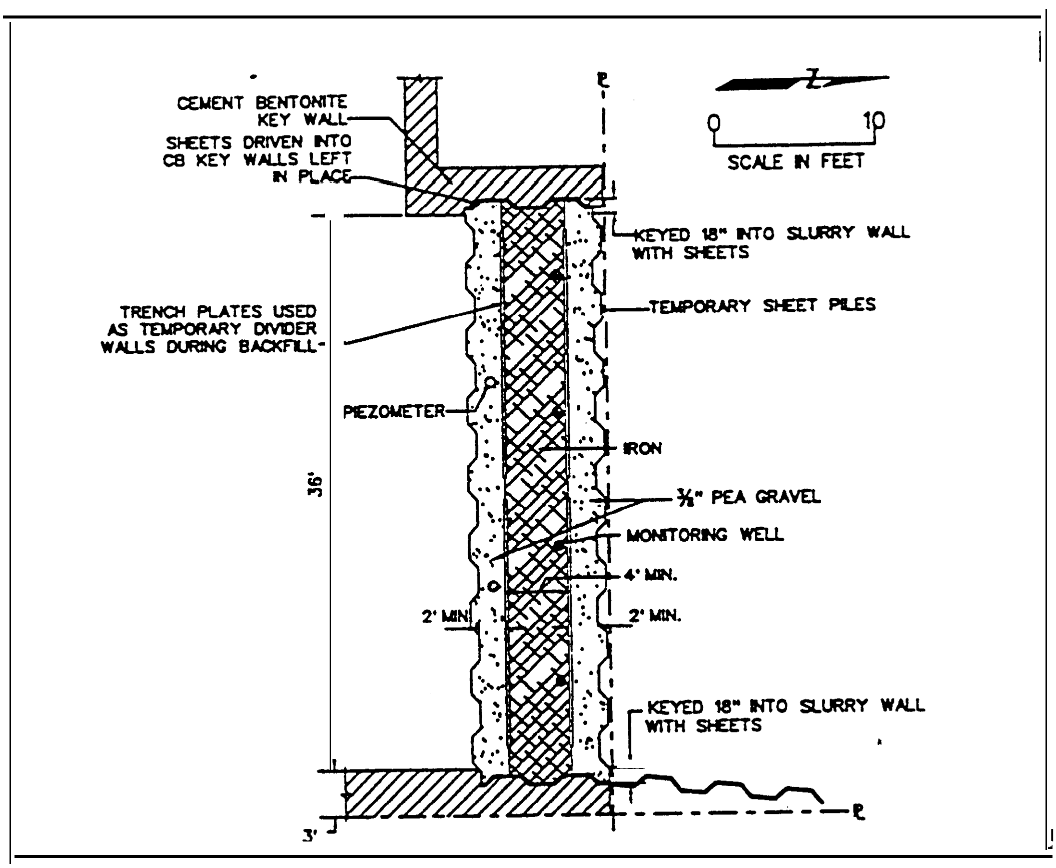




**Figure E-4. Design Plan for the Permeable Barrier Installed at the Intersil Facility, Sunnyvale, CA, Showing (a) Plan View of Funnel-and-Gate System and (b) Sectional View Through the Gate (Szerdy et al., 1996)**

## SITE 5: USCG Support Center, Elizabeth City, NC

SITE CHARACTERISTICS:
The site geology has been described in detail elsewhere (Puls et al., 1994a, b) It essentially consists of typical Atlantic coastal plain sediments, characterized by complex and variable sequences of surficial sands, silts, and clays. Groundwater flow velocity is extremely variable with depth, with a highly conductive layer at roughly 4.5 to 6.5 meters below ground surface. This layer coincides with the highest aqueous concentrations of chromate and chlorinated organic compounds. The groundwater table ranges from 1.5 to 2.0 meters below ground surface.

BENCH-SCALE TESTS:

*Batch Tests:* Transformation rates for chromate were faster for Ada Iron than Master Builders Iron and about the same for Peerless Iron. Transformation rates were faster for iron-aquifer mixtures than for 100 percent iron (true for both chromate and chlorinated compounds).

*Column Tests:* Column tests for Ada Iron (100 percent volume) - Aquifer sediment mixture effectively removed all chromate (5-10 ppm influent concentrations) for more than 1,500 pore volumes. Half-lives, estimated by fitting first-order decay equation to experimental data, were 1.9, 3.5, and 6.4 for TCE, c-DCE and vinyl chloride, respectively.

PILOT-SCALE FIELD TEST:
Two sources of iron were mixed with native aquifer material and a 10-mesh washed sand for use in the field test. The four materials were mixed in equal volumes on site and poured through 16-centimeter-inside-diameter hollow-stem augers. The system was installed in September 1994. The estimated diameter of the emplaced reactive iron mixture cylinders was 20 centimeters, and they were installed from 3 to 8 meters below ground surface. A total of 21 cylinders were installed in three rows like fence posts. A 4-meter section of the plume at the site was treated with this pilot test.

*Monitoring:* 25 monitoring wells were installed within the approximately 27.5 $m^3$ treatment zone, in addition to seven upgradient reference wells and five downgradient wells. Monitoring before and after "fence" installation was conducted for pH, Eh, dissolved oxygen, alkalinity, total chromium, chromate, total iron, ferrous iron, sulfide, and major cations and anions.

FULL-SCALE FIELD TEST:
A continuous trench system was installed in June 1996 (Figure E-5). The 100% Peerless Iron wall was installed using a trencher which excavated soil and filled in behind with iron in one pass (Figure E-6). The iron trench was 150 feet long, 24 feet deep (bgs) and 2 feet wide or thick. Time for installation was approximately 7 hours. This 150-foot wall will intercept two overlapping plumes (chromate, chlorinated solvent compounds [TCE, DCE, VC]). Residence time of groundwater was designed for approximately 3-4 days. Maximum influent contaminant concentrations are about 6 ppm, 12 ppm, and 0.1 ppm for chromate, TCE, c-DCE, and vinyl chloride, respectively.

*Monitoring:* 10 compliance (2-inch) monitoring wells (4 upgradient, one in wall, 5 downgradient), 15 multilayer samplers (145 sampling ports).

COST:
The full-scale barrier installation cost approximately $350,000.

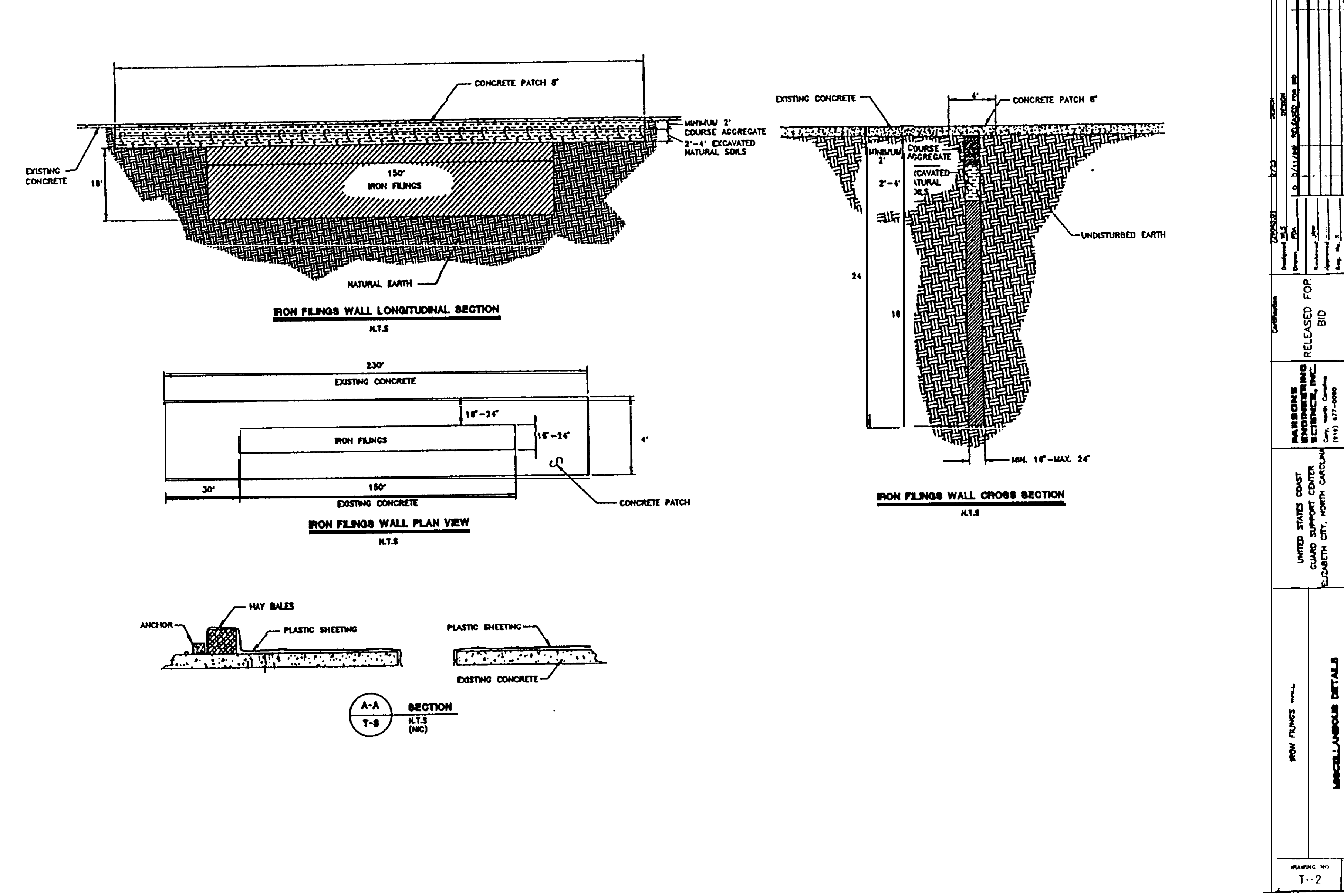



Figure E-5. Design Plan for the Permeable Barrier Installed at the USCG Facility, Elizabeth City, NC (Schmithorst, 1997)


**Figure E-6. Continuous Trencher Simultaneously Excavating a Trench and Refilling it from Behind with Granular Iron, Elizabeth City, NC (ETI, 1997)**

**SITE 6: NEW JERSEY, Industrial Facility**

SITE CHARACTERISTICS:

A thin layer of silty clay (2.5 to 3.5m) overlies fractured bedrock. Groundwater with maximum concentrations of 50,000 µg/L PCE and 3,000 µg/L TCE and TDS from 425 to 450 mg/L have been found in the permeable zone at overburden-bedrock contact.

BENCH-SCALE TESTS:

*Column test*: Columns were filled with 50% granular iron and100 percent granular iron (commercial iron that would be used). Tests were conducted at flow velocities of 1.5 ft/day using water collected from site. Concentrations present in the water: 4000-1200 µg/L of PCE, 1000 µg/L of TCE, and approximately 150 µg/L *c*-1,2 DCE. DCE would increase to 450 µg/L near the influent end of the column, then degrade. VC would also be produced (14 µg/L maximum concentration) then degrade.

*Half-lives:* At 50 percent iron and 100 percent iron, the half-life of PCE was 0.7 hour and 0.4 hour respectively; TCE, 1.1 hours and 0.5 hour. Half-lives in 100% iron column for cDCE and VC were 1.5 and 1.2 hours. For the second test, conducted with only 100 percent iron columns, the half-lives of cDCE and VC varied considerably from the initial test (3.7 and 0.9 hours, respectively).

*Inorganic results:* The pH of groundwater increased and calcium carbonate precipitation occurred. Because the amount of dissolved iron in the effluent was less than would be expected from independent measurements of corrosion rate, iron carbonate and/or iron hydroxide precipitation was thought to have also occurred within the column.

*Implications for the field:* Although mineral precipitation is a concern, precipitation at the site may be less than predicted by laboratory results.

PILOT-SCALE FIELD TEST:

A pilot-scale aboveground field trial was designed and initiated in November 1994. The system consisted of a fiberglass tank 2.44 m in diameter and 2.44 m high with 100% granular iron 1.68 m in depth. Water was pumped from a trench collection system to the top of the reactor, with downward flow through the reactor. To prevent atmospheric oxygen from entering the reactor, the surface was covered by ponded water. Residence time within the system was 24 hours. If successful, an in situ reactive section will be designed for use with the groundwater collection system.

*Monitoring:* Monitored under the U.S. EPA's Superfund Innovative Technology Evaluation (SITE) program. Side ports along the reactor allow sampling. Concentration profiles for 30 and 60 days of operation suggest canister is performing as predicted.

COST: NA

## SITE 7: CANADIAN FORCES BASE, Borden, Canada

SITE CHARACTERISTICS:
Unconfined aquifer of medium- to fine-grained sand about 9 m in thickness underlain by clayey silt deposit. Groundwater velocity is 9 cm/day and flow direction varies about 30 degrees. A continuous contaminated plume was generated from a small portion of aquifer that was brought to residual saturation with respect to nonaqueous liquid mixture of TCE, PCE, TCM (of which TCE and PCE remained at time of study). Plume is 4 m below ground, 1 m below water table, and is 2 m wide and 1 m thick, Maximum concentration is 250,000 μg/L and 43,000 μg/L for TCE and PCE, respectively.

BENCH-SCALE TESTS:

*Batch tests:* Preliminary lab tests showed industrial scrap iron filings produced rapid and extensive reduction of dilute aqueous chlorinated solvents.

*Column test:* Twenty-two wt % iron and 78 wt % sand were used. Groundwater flow was 32 cm/day. Simulated groundwater with 200 mg/L $CaS0_4$ was used.

*Half-lives:* TCM, TCE, and PCE had half-lives of 2.4, 19.7, and 23.5 hours, respectively.

*Inorganic results:* Reaction declined with increasing pH, remaining steady until pH 9.5.

*Implications for the field:* As flow velocity increased, the concentration profile became more elongated. However, dynamic flow conditions may improve degradation through removal of OH- produced in reaction by maintaining lower pH values. High levels of pH could impact system effectiveness.

PILOT-SCALE FIELD TEST:
*Type of system:* Reactive permeable wall was constructed 5 m downgradient from source (Figure E-7). Twenty-two wt % granular iron, 78 wt % concrete sand were used. The iron was grindings from a foundry operation. The wall was 1.5 m thick, constructed by driving sheet piling to form a cell 1.6 m wide and 5.5 m long. Sealable-joint sheet piling (developed by Waterloo) was used to construct the rectangular cell at the surface and then driven to depth of 9.7 m, where sheet piling was then removed. Residence time was 16 days. (Figures are available.)

*Monitoring* Two monitoring wells were located upgradient, 6 within the wall and 3 downgradient. Rows of multilevel samplers were located 0.5 m upgradient, at distances of 0.5 and 1.0 m into the wall, and 0.5 m downgradient from the wall for a total of 348 sampling points. However, the shape of the plume and the changing flow direction made monitoring difficult. Core sample of reactive material taken 3.5 years after installation showed performance had not changed significantly. A sample taken at 12 months showed that biological activity was low. Performance remained consistent during the entire 17-month period. Final results showed that 90% TCE and 88% PCE were removed, but concentrations were still above MCL, which did not match lab predictions.

COST: NA

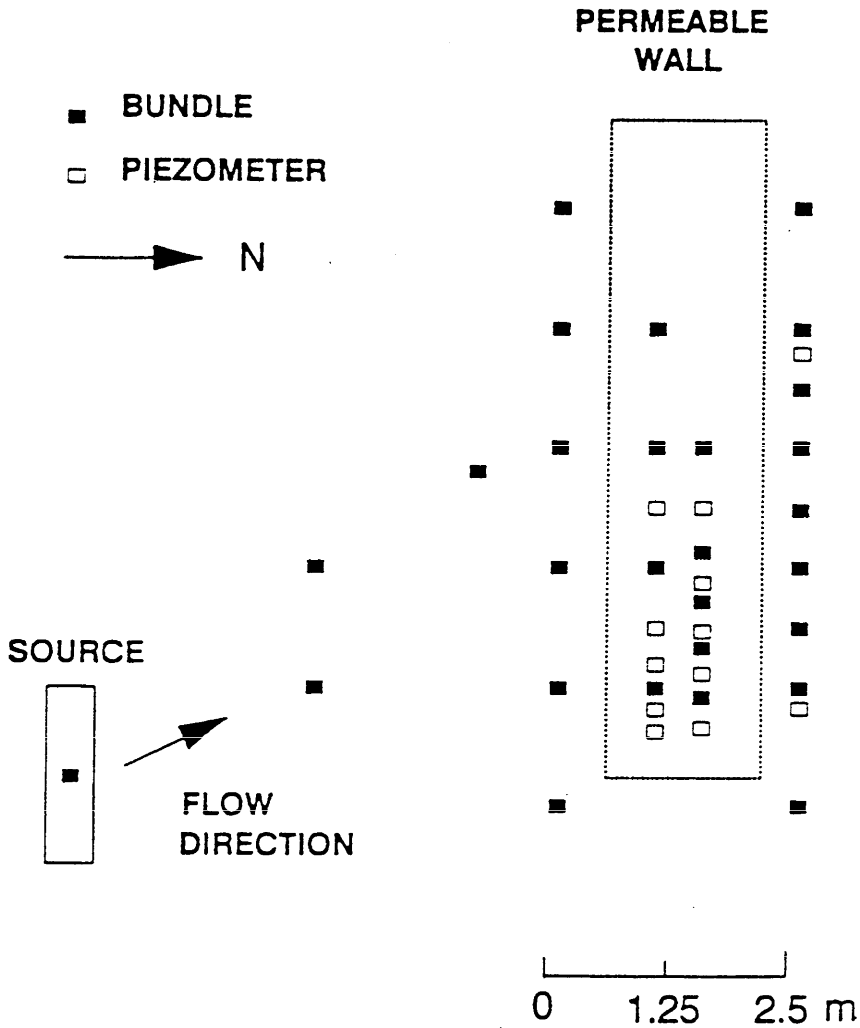



**Figure E-7. Design Plan for the Permeable Barrier Installed at the Canadian Forces Base, Bordon, Canada (O'Hannesin, 1993)**

## SITE 8: DENVER FEDERAL CENTER, Lakewood, Colorado

SITE CHARACTERISTICS:
The full-scale funnel and multiple gate system along the eastern boundary of the Denver Federal Center is the largest one installed to date. Groundwater flow is northeasterly with an east-northeast component. Flow rates are about 0.50 ft/day through a subsurface alluvium formation and 0.70 ft/day though a weathered bedrock formation. The contaminant plume was beginning to move off site towards an elementary school. Contaminants include 700 ppb of TCE, 700 ppb of DCE isomers, and 15 ppb of vinyl chloride.

BENCH-SCALE STUDIES:
Since the project was under a Rapid Response contract, bench-scale studies were performed in a limited time frame. However, half-lives of about 1 hour or less were measured for the above-mentioned compounds. Gate velocities are expected to range between less than 1 ft/day to about 10 ft/day.

FULL-SCALE FIELD TEST:
The funnel-and-gate system was completed in October 1996. The funnel walls, comprised entirely of sealable-joint sheet piling, extend about 1,040 feet and range in depth from 26 to 32 feet below ground surface (bgs). Four equally spaced gates were installed using the sheet pile box method in which native material was excavated from the box and replaced with an iron filings and pea gravel media (Figure E-8). Each gate is 40 feet wide, approximately 20 feet bgs, and houses an iron wall from 2 to 6 feet thick.

*Monitoring:* Up to 15 shallow monitoring wells, 3 deep monitoring wells, and 10 piezometers were installed both upgradient and downgradient of the permeable barrier and within the reactive cells. Sampling initially occurred biweekly, then changed to monthly, and finally scaled back to quarterly events.

COST: NA

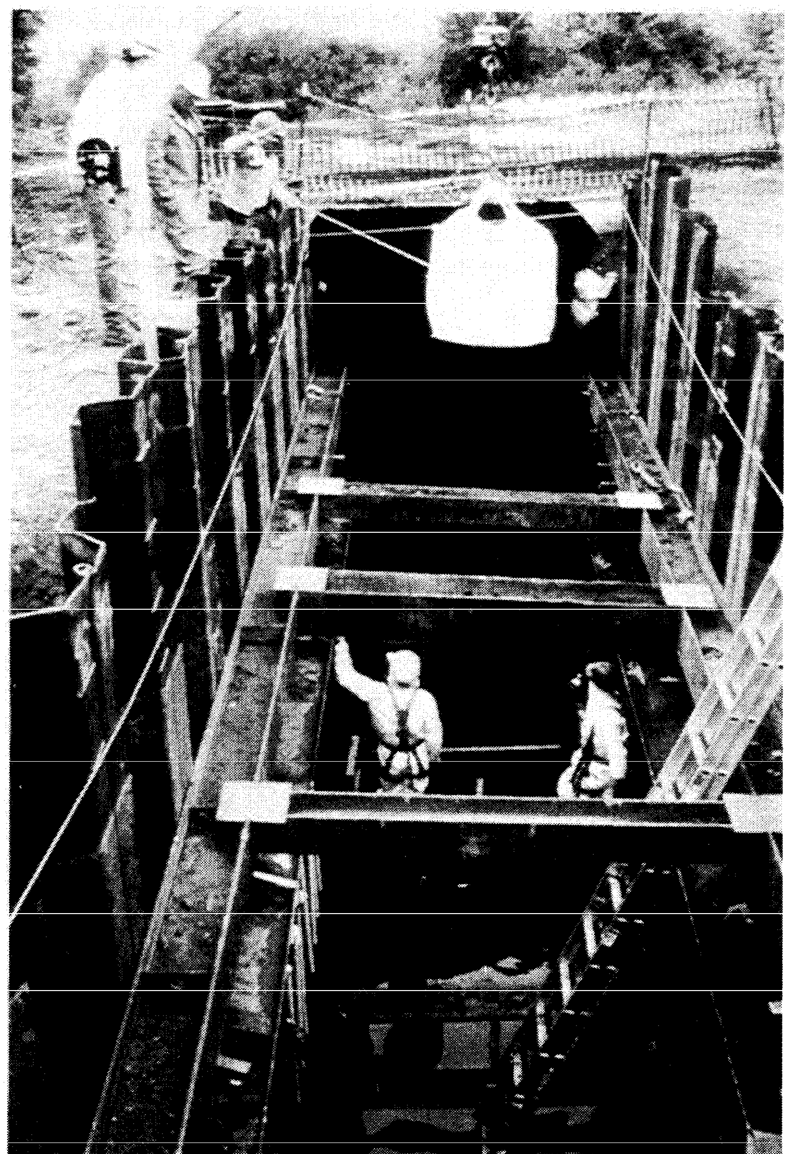


**Figure E-8. Construction of One of Four Gates Installed at the Denver Federal Center, CO (ETI, 1997)**

## SITE 9: MOFFETT FEDERAL AIRFIELD, Mountainview, California

SITE CHARACTERISTICS:
An extensive site characterization investigation was conducted which included four pumping tests and multiple cone penetrometer pushes. The hydrogeologic setting at the permeable barrier site consists of a complex mixture of alluvial-fluvial clay, silt, sand, and gravel sediments which form a series of lens-shaped, interbraided channel deposits that are divided into three separate aquifers, A, B, and C aquifers (PRC, 1993). Aquifer A consists of Al and A2 aquifer zones and is approximately 65 feet thick, The Al aquifer zone extends from 5 to 25 feet bgs and is separated from the underlying A2 aquifer by a 0 to 15 ft thick semiconfining clay layer. The A2 aquifer zone is up to 25 ft thick. The funnel-and-gate barrier was strategically emplaced within the A1 aquifer zone, utilizing the semiconfining clay layer as a bottom barrier. Contaminants which include waste oils, solvents, cleaners, and jet fuels, originate from above and underground storage tanks, a dry cleaning facility, and sumps. A chlorinated VOC plume exists mainly in the A aquifer and is more than 10,000 ft long and 5,000 ft wide. TCE levels are greater than 20 mg/L and PCE levels were about 0.5 mg/L.

BENCH-SCALE TESTS:

*Batch tests:* An iron sample from Peerless Metal Powders Inc. proved to show the greatest treatment efficiency for TCE and PCE and was the only sample used in the column tests. Both buffered and unbuffered solutions were tested to determine the correlation between pH and half-life. Neither solution showed significant reaction rates, so it was decided that the permeable barrier at Moffett Air Field would be left unbuffered.

*Column tests:* Calculated permeablilites through a column of 90% sand and 10% iron mixture averaged 216 ft/day and porosities were reported to be about 38%. The tests were performed using a calibrated flowrate of 7.7 ft/day.

*Half-lives:* Calculated half-lives were about 0.87 to 1.0 hr for TCE and 0.29 to 0.81 hr for PCE. Half-Iives were 3.1 hr for 1,2 DCE, 9.9 hr for 1,1-DCA, and 4.7 hr for vinyl chloride.

PILOT-SCALE FIELD TEST:
The 50-ft-wide permeable barrier was completed in April 1996 and is configured as a funnel-and-gate system (Figure E-9). The rectangular gate consists of a 100% zero-valent iron reactive cell bounded on either side by upgradient and downgradient sections of pea gravel. The iron cell is 6 ft thick, 10 ft wide, and 22 ft deep. The flanking pea gravel sections are 2 ft thick, 10 ft wide, and 22 ft deep. The funnel walls are constructed of sealable-joint sheet piles and are 20 ft long on either side of the gate. The system was installed in the middle of the plume and was not keyed into the underlying semiconfining clay to avoid a potential breakthrough of the thin layer. Residence time within the system is about 1.2 days.

*Monitoring:* Eighteen monitoring wells are located within the gate: ten within the reactive iron cell and four within each pea gravel section. Groundwater wells completed in the Al aquifer zone includes two upgradient and three downgradient wells. Groundwater wells completed in the A2 aquifer zone includes one upgradient and two downgradient wells. Sampling is conducted quarterly for VOCs, volatile hydrocarbons, inorganic, and field parameters including T, pH Eh, DO and water level.

COST: $375,000 (including iron)

**Figure E-9. Installation of a Gate at Moffett Federal Airfield, CA, Showing (a) Emplacement of Granular Iron from a Suspended 3,000-Pound Bag and (b) Removal of Temporary Upgradient Sheet Piles from Within the Gate (ETI, 1997)**

## SITE 10: MASSACHUSETTS MILITARY RESERVATION (Otis Air Force Base), Cape Cod

SITE CHARACTERISTICS:
The site encompasses 22,000 acres. At least ten plumes more than 3 miles long have contaminated at least 53 billion gallons of groundwater at the site. Pilot installation of a continuous reactive barrier composed of nickel-plated iron filings was tentatively scheduled to begin November 1996. It was planned that two parallel 50-ft reactive walls, 25 ft apart, perpendicular to a 600-ft wide plume, would be emplaced. The top of the walls will be installed at 80 ft below ground surface and extend down to 110 ft. Contaminants in the plume consist of 5 to 150 ppb TCE and PCE.

BENCH-SCALE TESTS:
Laboratory trials using nickel-plated iron can degrade compounds up to 10 times faster than do zero-valent iron filings alone. Half-lives for TCE and PCE were determined to occur every 7 to 10 minutes. Secondary products created during the breakdown of TCE and PCE, such as vinyl chloride and *cis*-DCE, are produced in smaller concentrations with nickel-iron than iron alone.

PILOT-SCALE FIELD TEST:
The continuous reactive wall will be emplaced using the vertical hydraulic fracturing technique. The technique requires 1-ft-diameter boreholes to be drilled down to the top of the zone of contamination. A fracture is then induced and filled with iron filings suspended in a slurry mixture. The propagating fracture will form a series of overlapping vertical planes that become a “continuous” wall. Nine of 23 monitoring wells have already been installed.

IMPLICATIONS FOR THE FIELD:
A faster degradation rate requires less residence time in the reactive cell. Therefore, the reactive wall planned for the Massachusetts Military Reservation for instance would only be 2 inches thick compared to an iron only wall that would have to be 10 inches thick. A potential drawback however, is the possibility of nickel leaching from the iron and contaminating the treated groundwater as it passes through the reactive wall.

COSTS:
Pilot-scale barrier cost of approximately $500,000 for two years.

## ADDITIONAL SITES

### SITE: Somersworth Sanitary Landfill Superfund Site, New Hampshire

SITE DESCRIPTION:
The principal contaminants include TCE, *cis*-DCE, and VC with concentrations less than 300 μg/L. The contaminant plume is approximately 400 feet long, 300 feet wide, and 35 to 40 feet deep and moving at a groundwater velocity of 1.5 to 2.0 ft/day. The water table at the site is high, and most of the 43 to 44 feet of excavation soil was saturated.

PILOT-SCALE FIELD TEST:
A pilot-scale funnel-and-gate system was installed in November 1996 (Figures E-10, E-11). The system design consists of using an 8-foot-diameter caisson for emplacing the reactive cell and two 30-foot-long, 4-foot-thick soil/bentonite slurry walls for the funnel sections. The gate was to be installed to a depth of 43 to 44 feet. Iron filings and coarse sand were the reactive media selected.

COSTS:

| | |
|---|---|
| Mobilization | $30,000 |
| Slurry walls (funnel walls) | $35,000 |
| Caisson gate installation | $60,000 |
| Site preparation/Waste management | $20,000 |
| Design engineering | $30,000 |
| Total | $175,000 |

### SITE: Mountainview, CA, Private Electronics Firm

The site consisted of very tight soils. A continuous iron wall was built between July and September 1995 to treat a plume containing cDCE (5 to 10ppm), TCE (up to lppm) and VC (5 to 50ppb). The remediation area covers 60 by 40 feet, and is 25 feet deep. Ninety tons of iron was used to construct the wall. The cost was about $80,000 to $100,000.

### SITE: Lowry Air Force Base, Denver, CO

Pilot installation of a funnel-and-gate system was finished in December 1995 (Figure E-12). Funnel consists of sealable-joint sheet piling, 15 ft on either side of iron gate. Gate is 10 feet wide, 3 feet thick, and 17.5 ft deep. Cost for construction was $105,000, and media were $32,500, for a total capital cost of $137,500. One to 2 ppm TCE was detected in influent groundwater.

### SITE: Military Facility, Minnesota

Minnesota Pollution Control Agency sponsored a laboratory study to determine if PCE, TCE, and c-1,2-DCE could be treated. Groundwater from the facility was pumped through columns containing 50% and 100% reactive iron. The half-lives of PCE for 50% and 100% iron were 0.8 and 0.7 hour, respectively; TCE, 0.5 and 0.4; c-l,2-DCE, 370 and 527.0 hours.

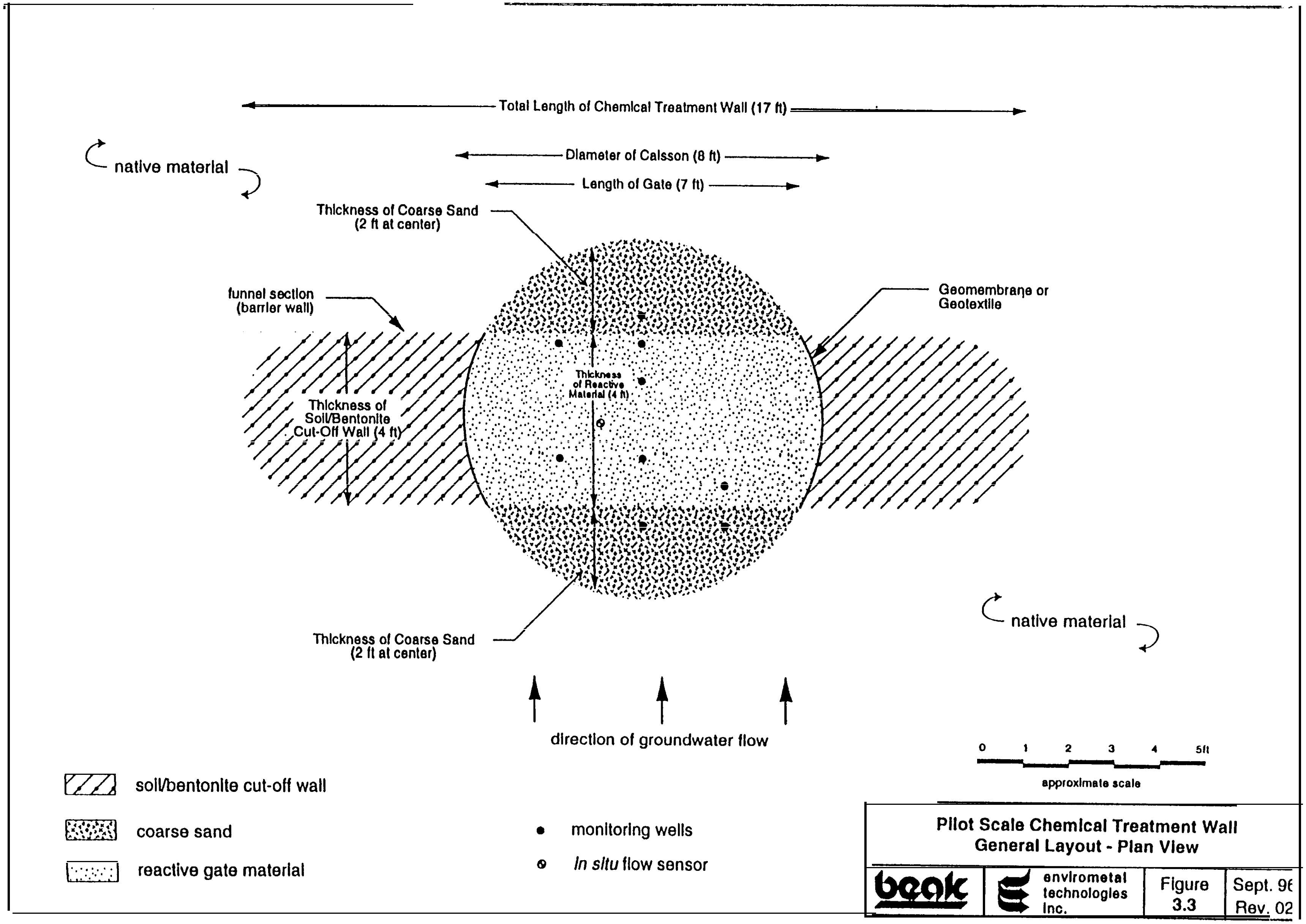



**Figure E-10. Design Plan for the Permeable Barrier Installed at the Somersworth Sanitary Landfill, NH – Plan View (ETI, 1996)**

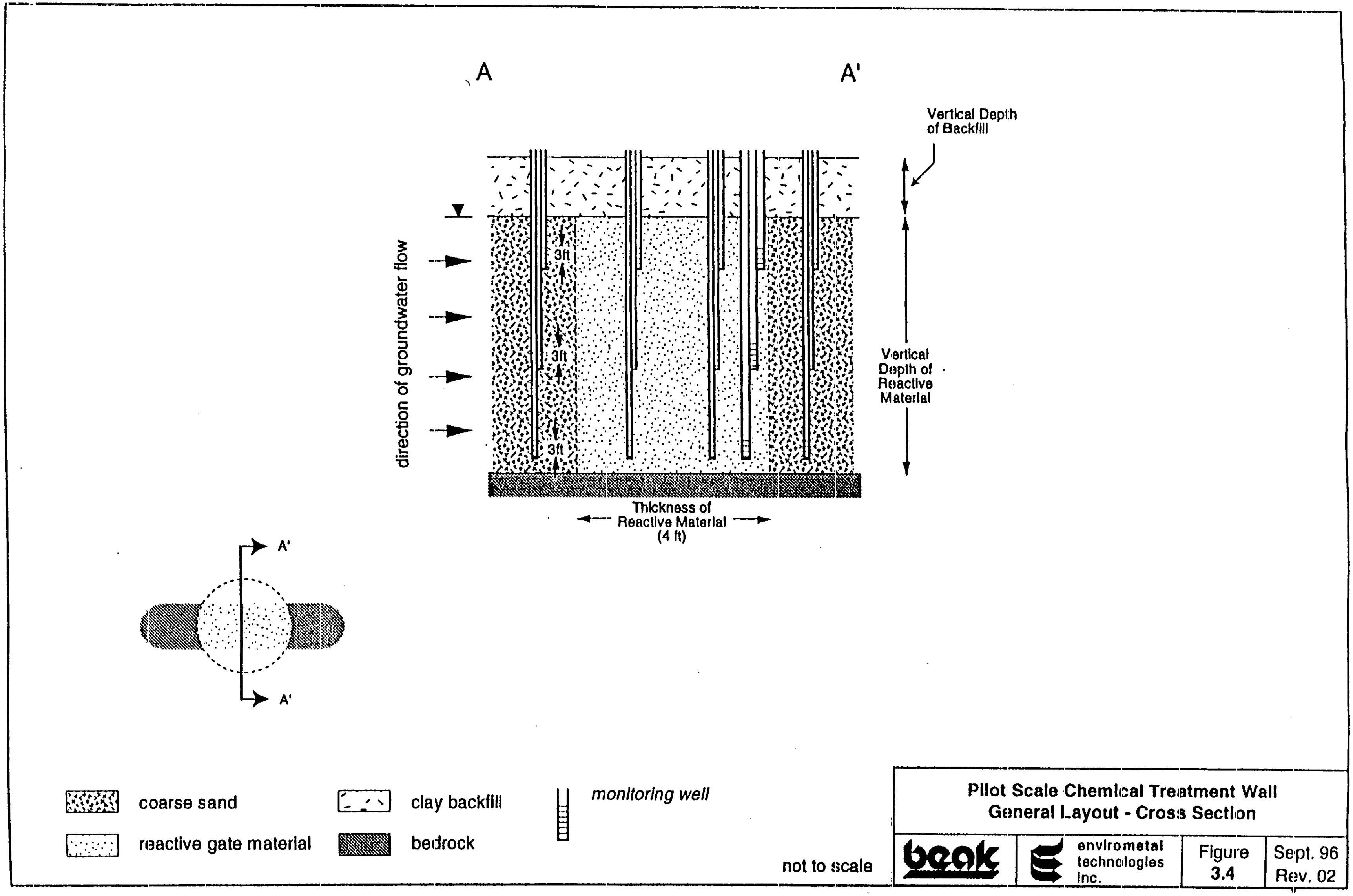



**Figure E-11. Design Plan for the Permeable Barrier Installed at the Somersworth Sanitary Landfill, NH – Cross-Sectional View (ETI, 1996)**

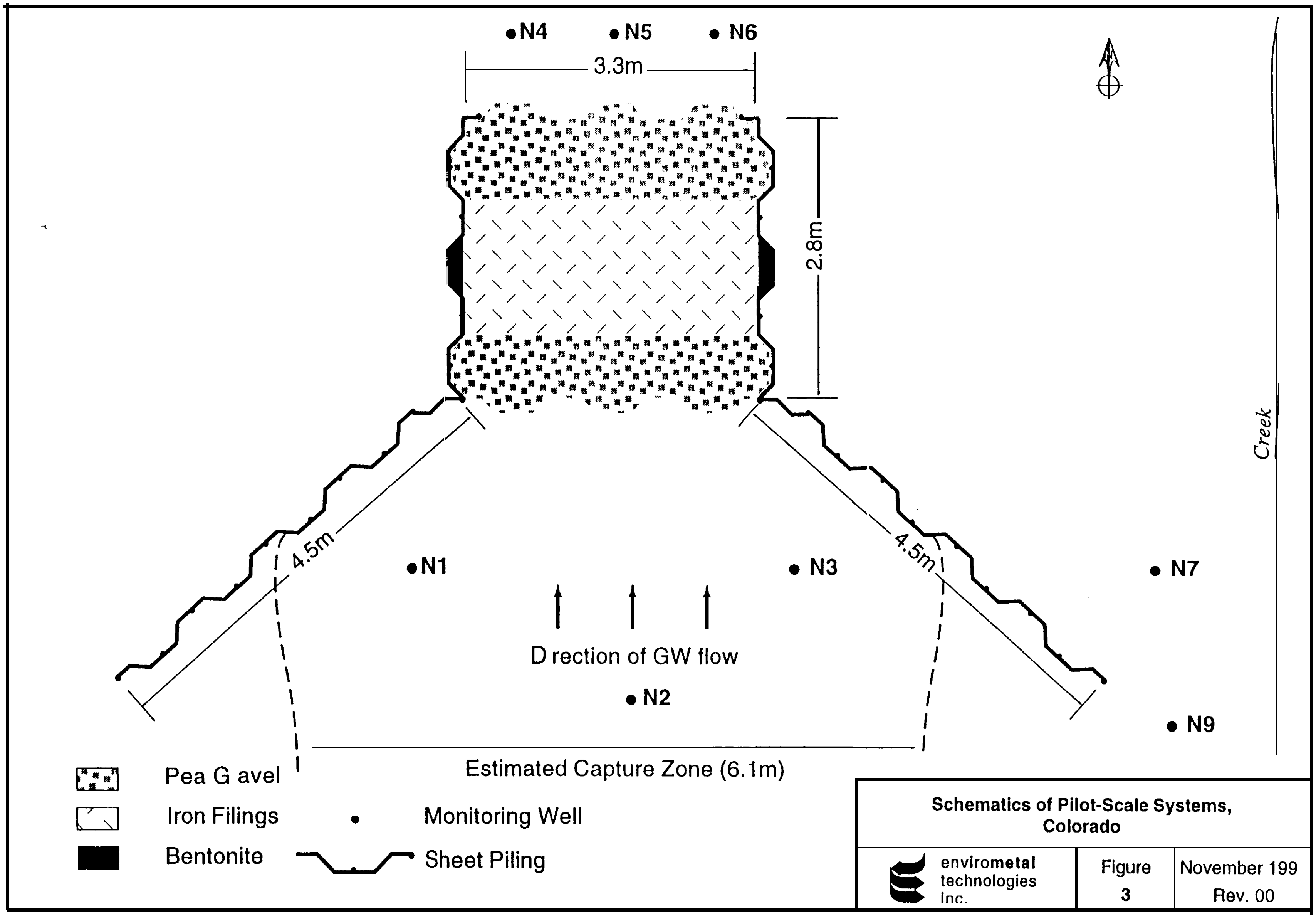



Figure E-12. Design Plan for the Permeable Barrier Installed at Lowry AFB, Denver, CO – Plan View (ETI, 1997)